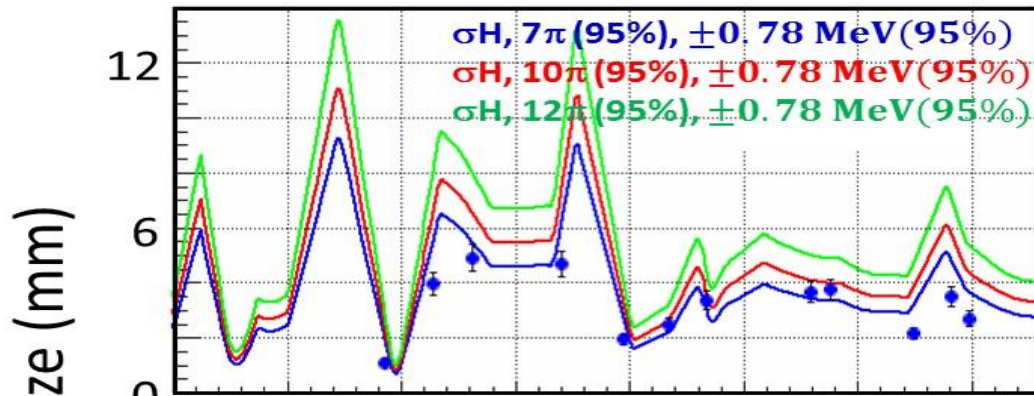


Compilation of Measured Beam Emittance of the Booster from 2015-2019

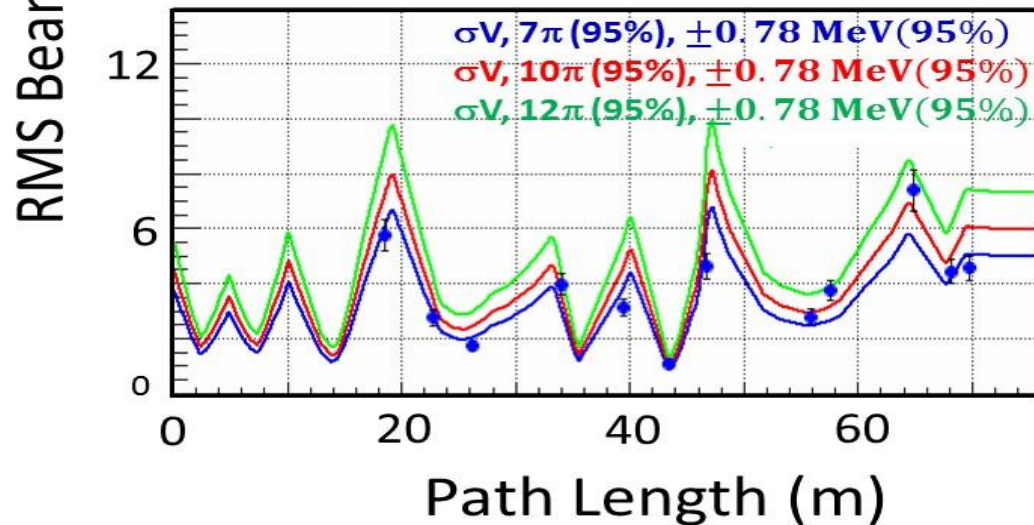
Chandra Bhat
PS Department, Accelerator Division
20190628

Acknowledgement: C. Y. Tan

400 MeV Lattice - MAD Beam Size - Horizontal



Beam Size - Vertical

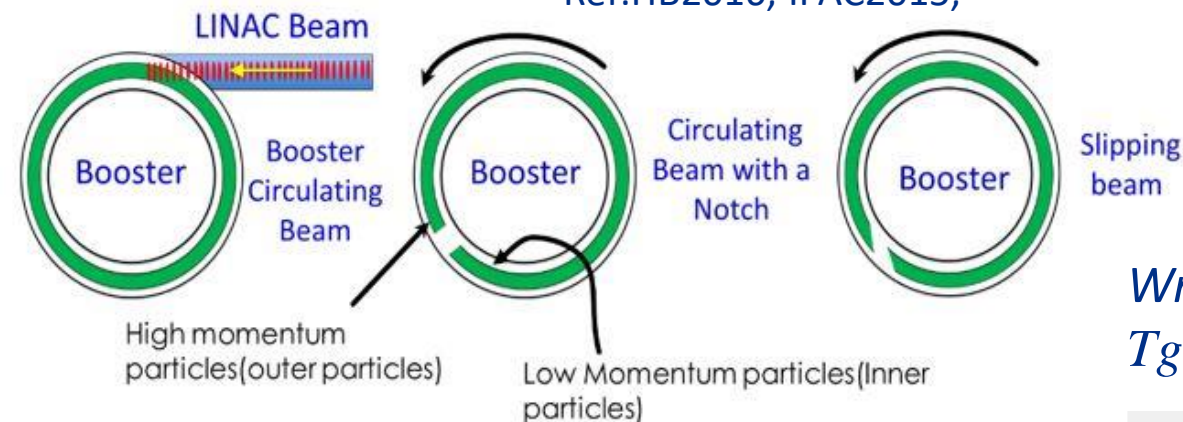


Data is consistent with
 $\Delta E(\text{full}) = 1.56$ MeV
 $\varepsilon_H = 7 \pi\text{-mm-mr}$
 $\varepsilon_V = 7 \pi\text{-mm-mr}$

But, this measurement
does not give info. on
multi-turn beam in the
Booster.

ΔE at Injection on Multi-turn Beam

Ref:HB2016, IPAC2015, FB-BPE-workshop-20151123-cbhat-pptx

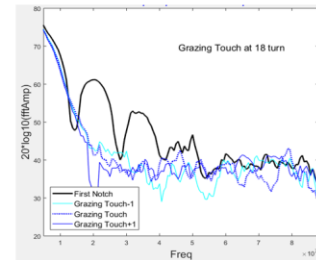
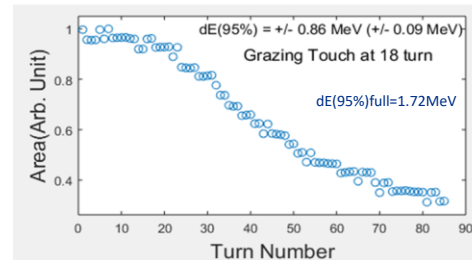
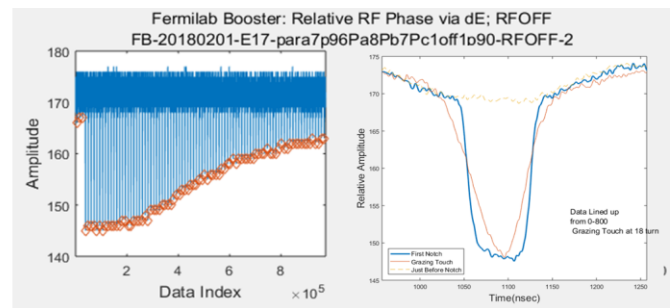
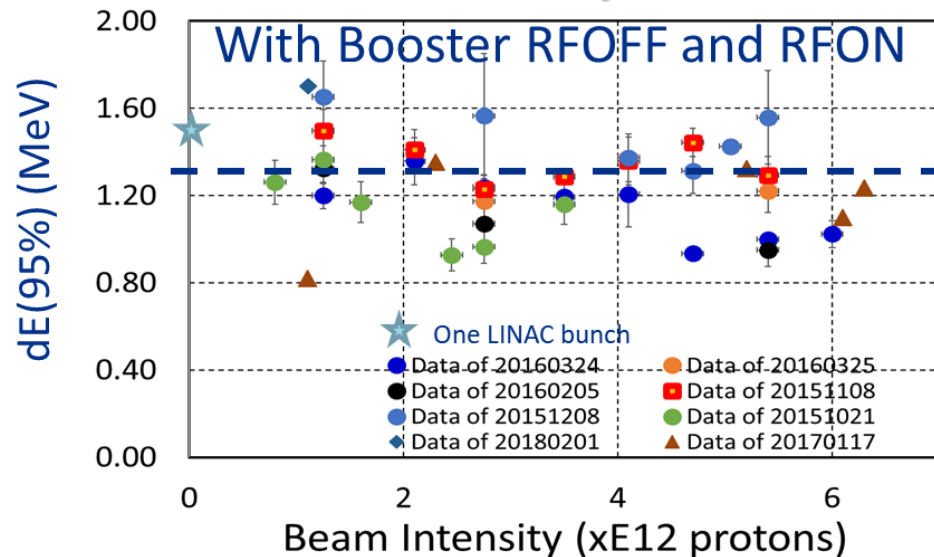


$$\Delta E = \frac{\beta^2 E_s}{|\eta|} \frac{W_{notch}}{T_{graze}}$$

W_{notch} = Width of the Notch

T_{graze} = Time for grazing touch

Ref: PIPWorkshop-talk2018cbhat-BD6294.pptx
dE Measurements -UsingB96.xls



$dE(95\%)_{full} = 1.25 \pm 20 \text{ MeV}$

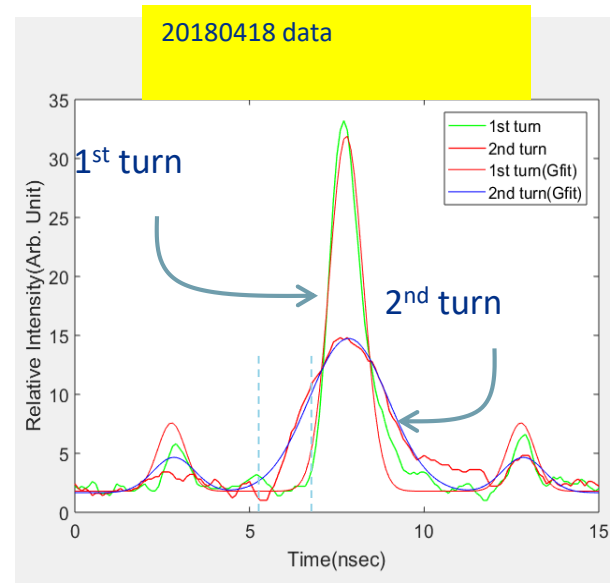
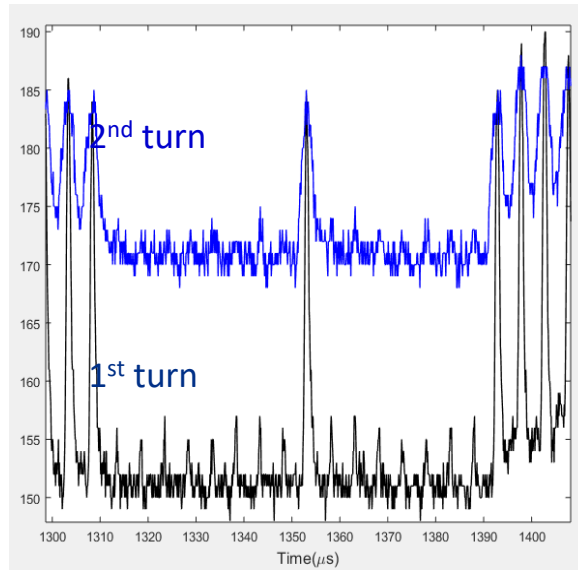
$p/p > 0.045\%$

Do not see increase in dE as a function of injected beam intensity in the range of 0.1-6.3E12

Measurement of dE at Injection

Ref: PIPWorkshop-talk2018cbhat-BD6294.pptx

With a single LINAC bunch in
the center of LASER Notcher



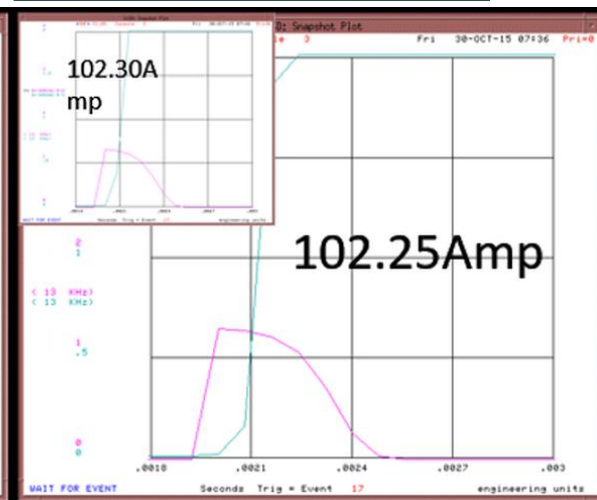
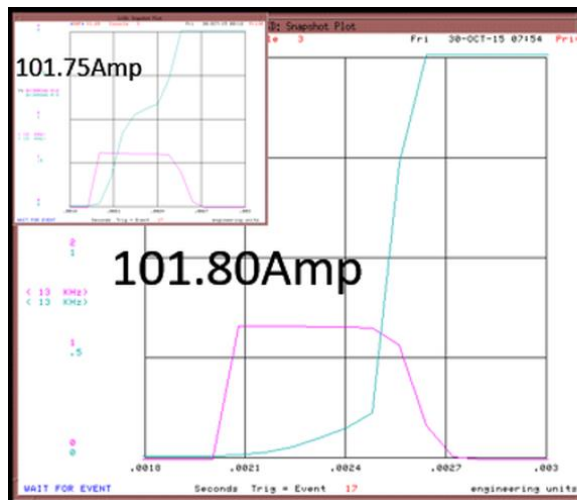
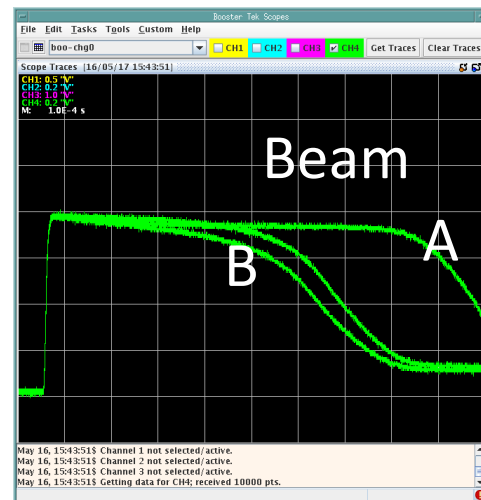
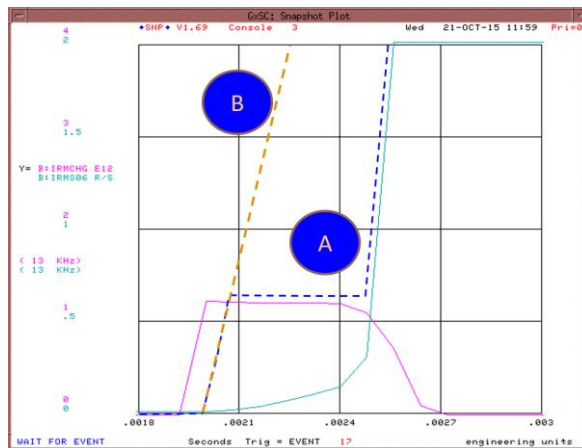
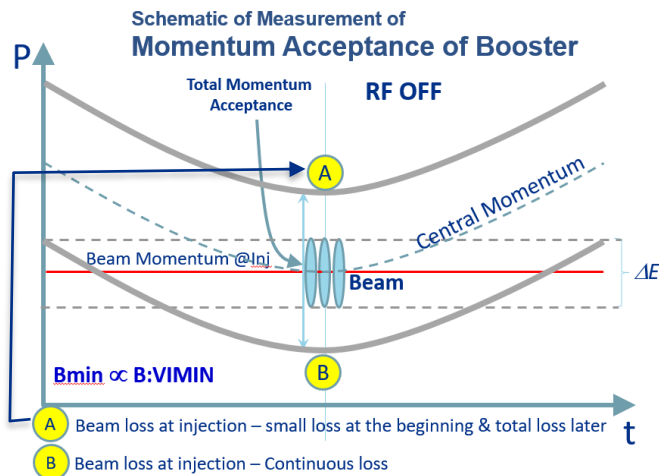
$$dE = 1.51 \pm 0.08 \text{ MeV (95\%)}$$

The dE from LINAC did not change over the years
RF OFF measurements are consistent with this result.

Momentum Acceptance of the Booster at Injection

Procedure: Inject 1-4 turn beam. Measure beam loss pattern as shown in two right pictures as a function of B:VIMIN.

An example



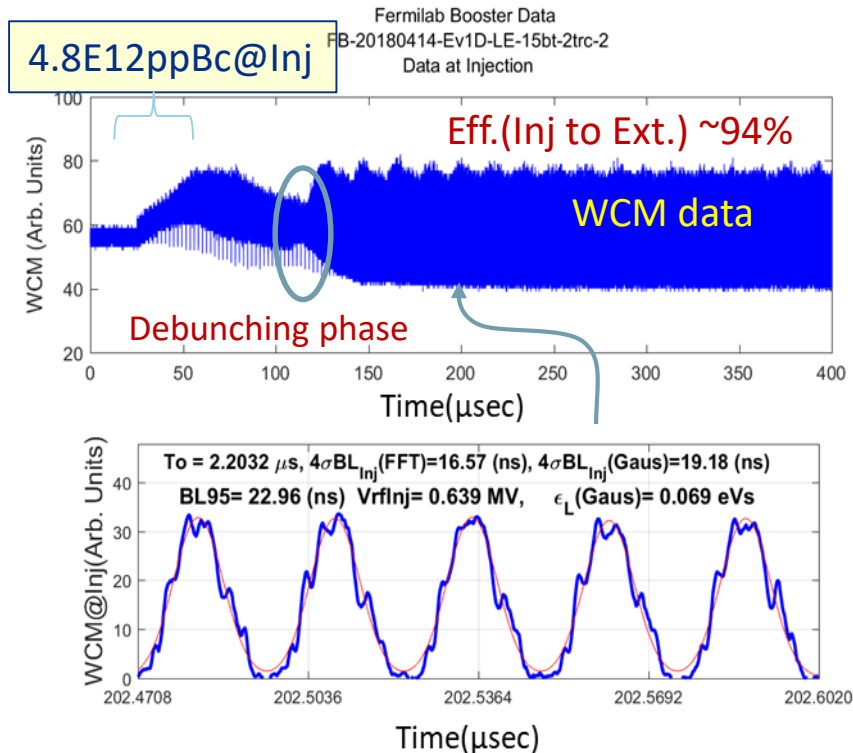
Date of Meas.	(with early injection scheme in place)			
20160205	Energy Acceptance =	5.06 ±	0.37	MeV
20170511	Energy Acceptance =	5.95 ±	0.46	MeV
20170516	Energy Acceptance =	5.15 ±	0.38	MeV
	Full Acceptance	5.39 ±	0.40	MeV

Acceptance~5 MeV

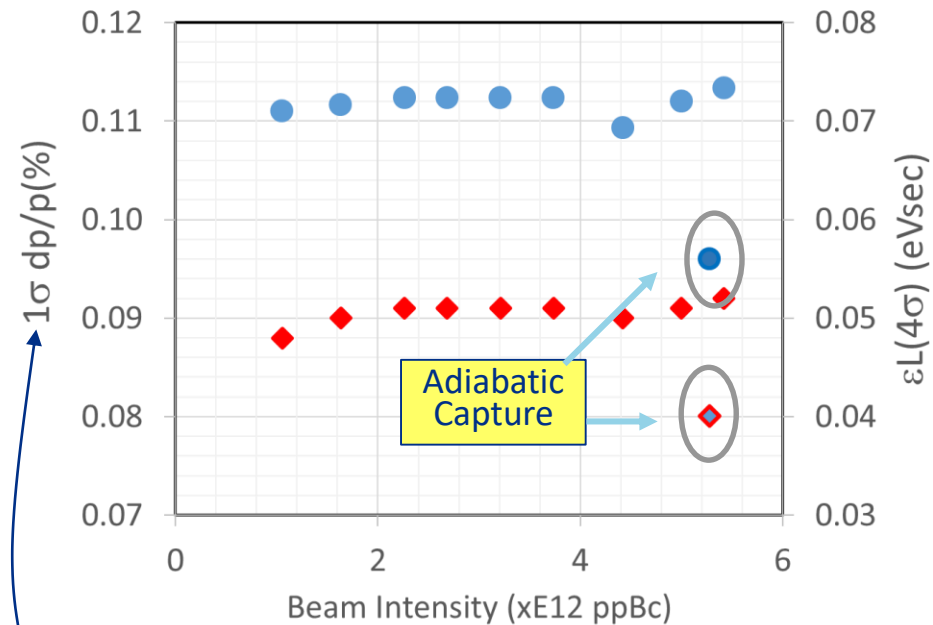
(We should try to keep $V_{rf} > 0.55$ MV by the end of the capture to keep full bucket height > 5 MeV)

ϵ_L After Beam Capture

Ref: PIPWorkshop-talk2018cbhat-BD6294.pptx



ϵ_L (@end of Capture)

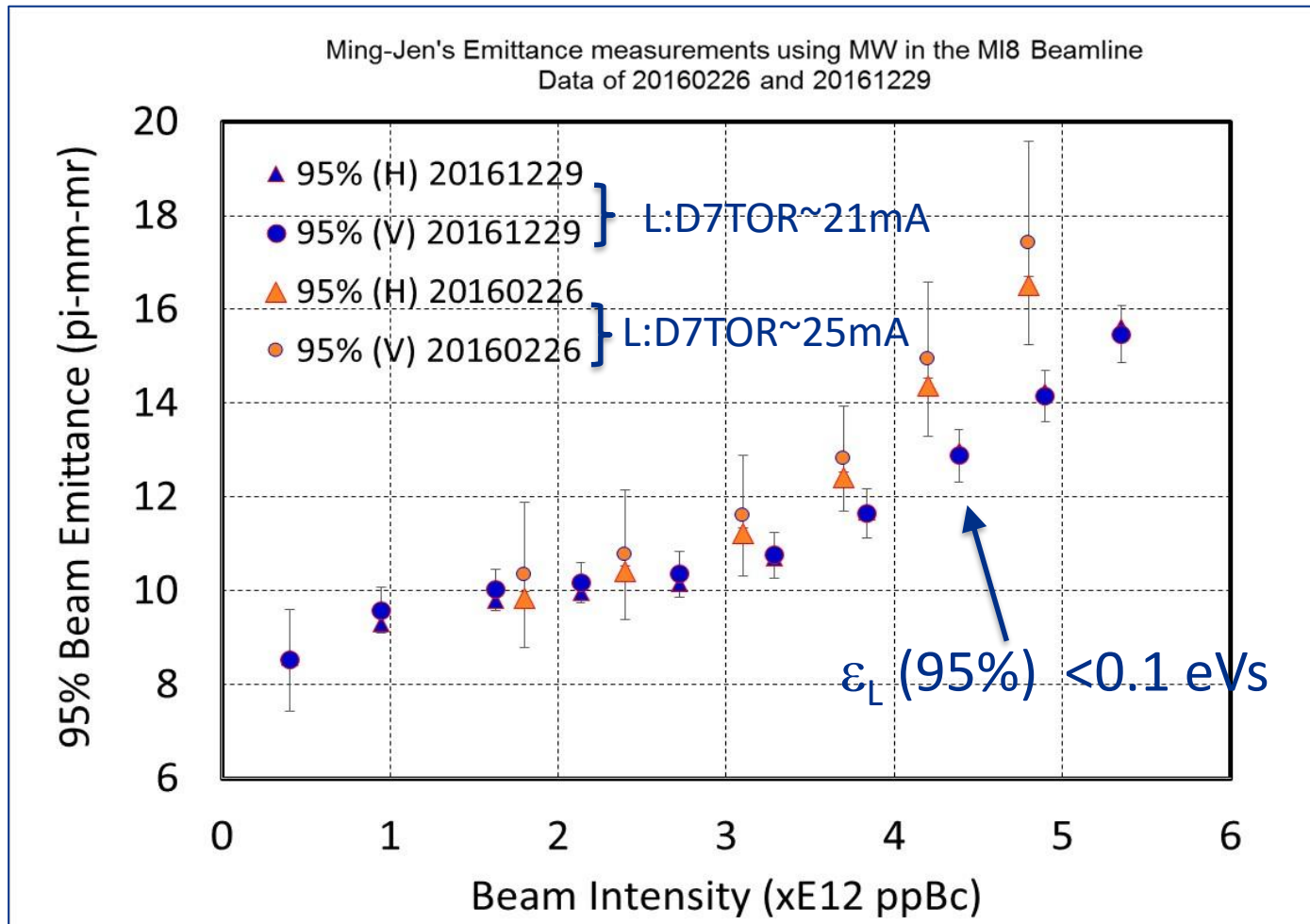


Note: The measured $LE(4\sigma)$ is accurate in this figure. However, the $1\sigma dp/p$ value is not correct. The correct value can be obtained by multiplying by a factor 2.

Observed $\sim 90\%$ ϵ_L growth from beam Inj. to end of Capture.

Measurements of 20160226 and 20161229 (after freq. based TX)

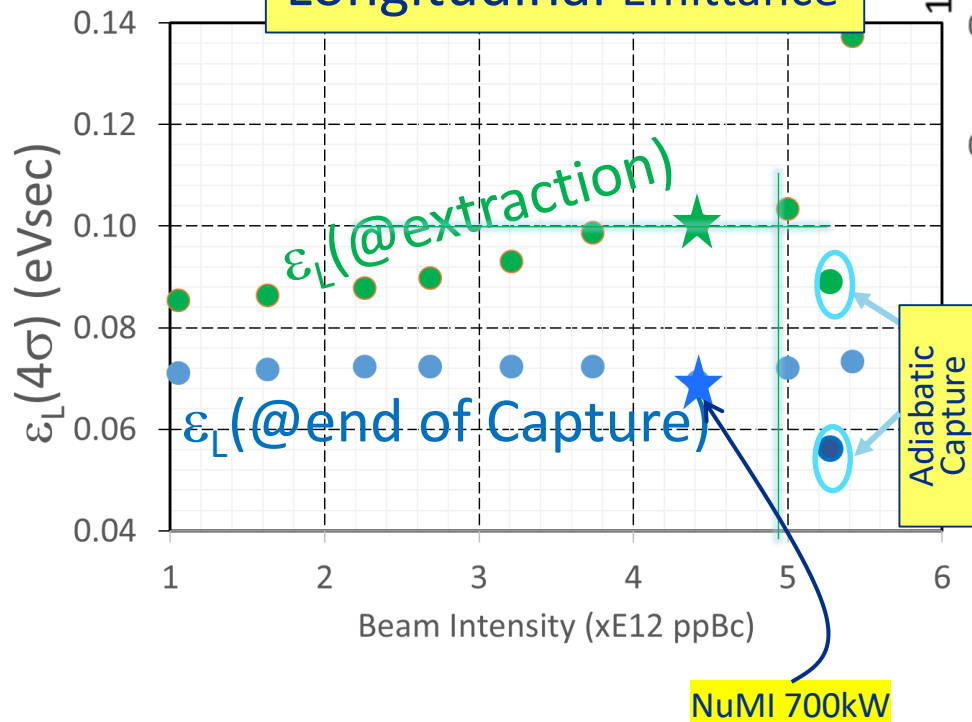
MI 8-Beamline-Emittance-20160226-1229-Beams-Doc-5675-v1.pptx



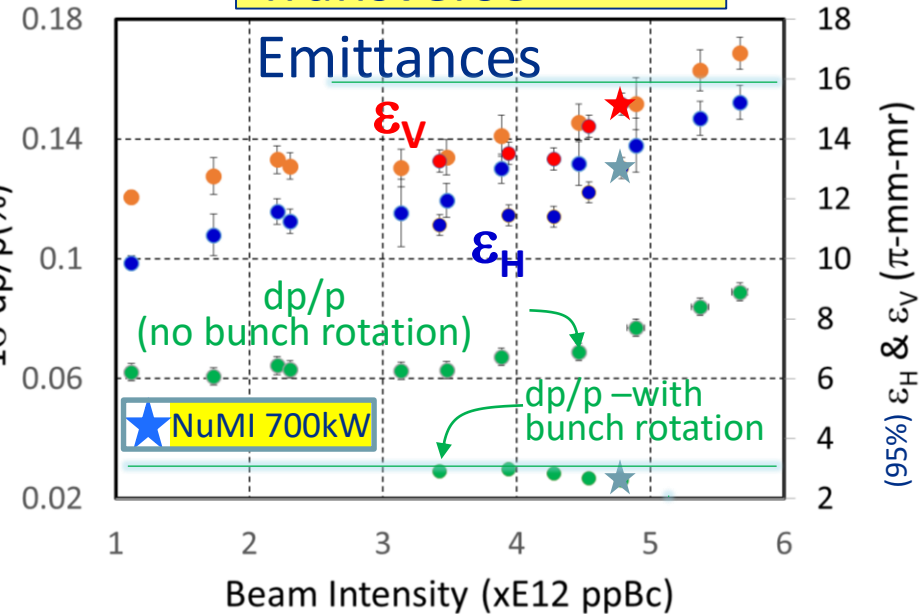
Beam Emittance Measurements

Booster is tuned for intensity required for 700kW on NuMI target and the intensity is varied during these measurements.

Longitudinal Emittance

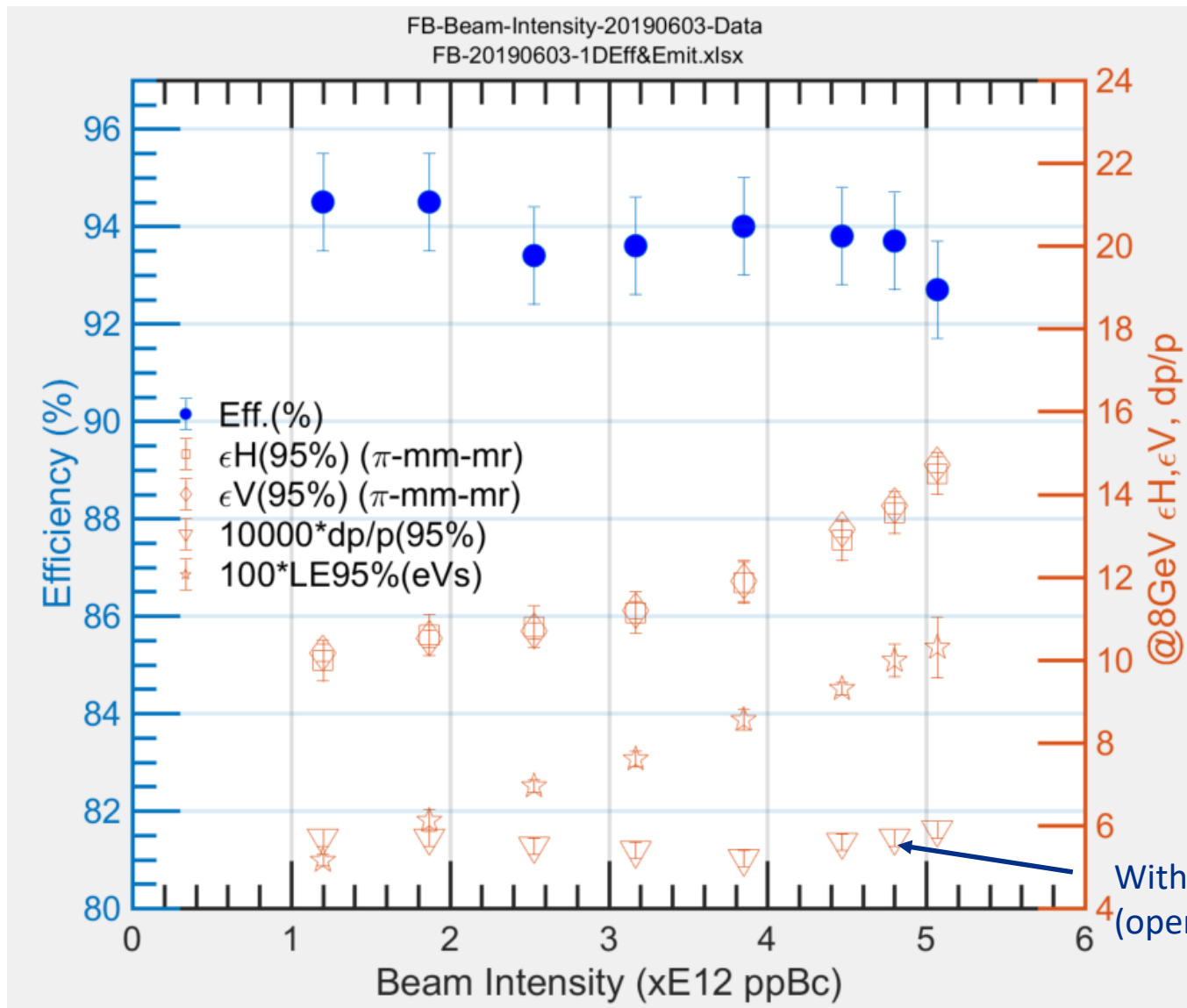


Transverse Emittances



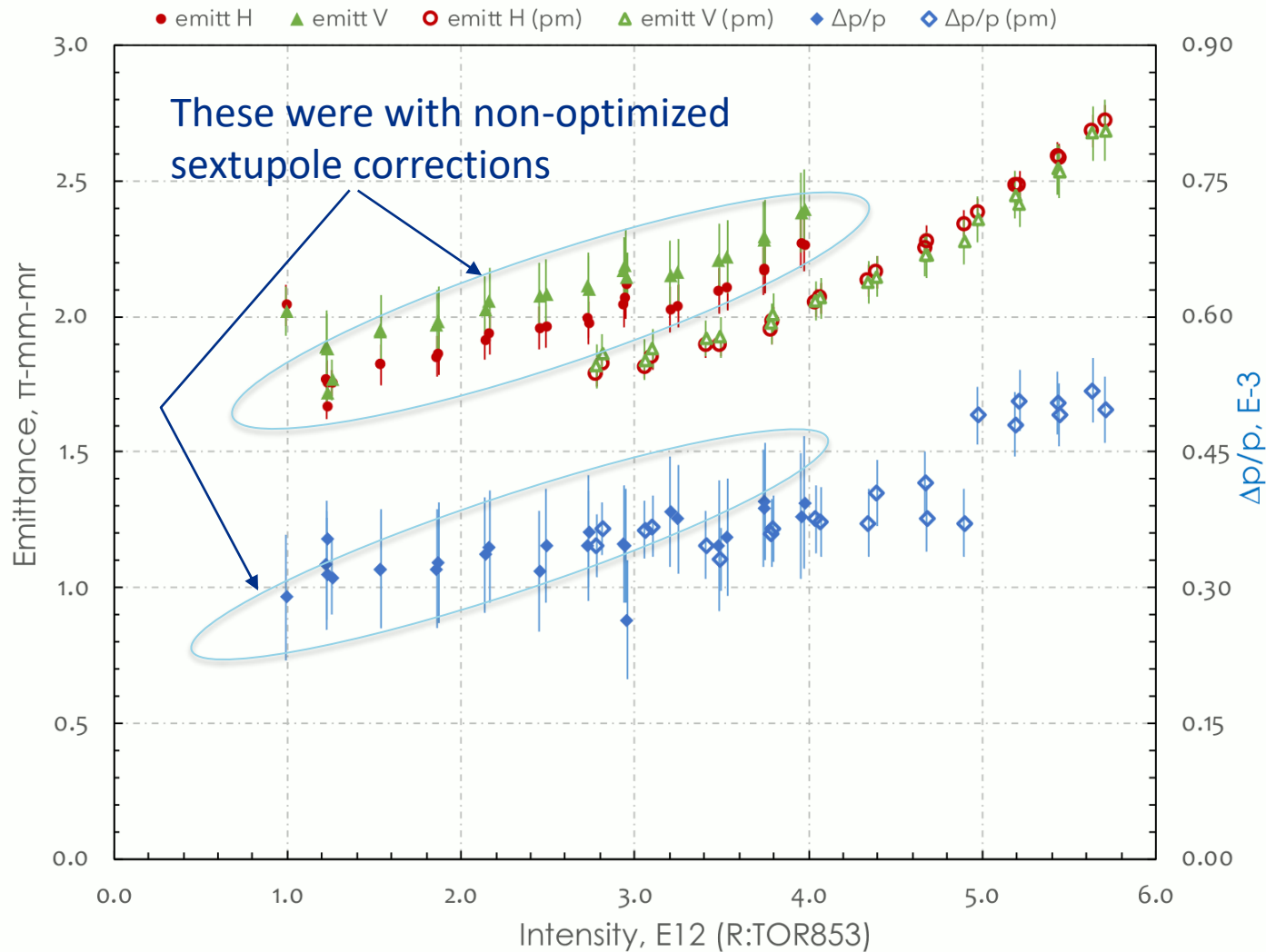
Ref: PIPWorkshop-talk2018cbhat-BD6294.pptx

Measurement of 20190603



Ref: BD-DOC-7376

Ming-Jen's Measurements of 20190628



Summary: Booster Emittance and Acceptance as of 20190628

	2E12ppBc (6-8BT)		~5E12ppBc (16BT)		
	Injection 400 MeV	Extraction 8 GeV	Injection 400 MeV	Extraction 8 GeV	
Momentum Acceptance (Full)	5.4±0.4	>30 *			MeV
dE(95%)	1.5±0.2	26±1	1.5±0.2	18±1	MeV
LE(95%)	0.07±0.01 @end capt.	0.09±0.01	0.07±0.01 @end capt.	0.1±0.01	eVs
Horizontal Emit. (95%)	7±1♣	11±1	--	14±1	π-mm-mr
Vertical Emit (95%)	7±1♣	11±1	--	14±1	π-mm-mr
Beam Transmission Efficiency Inj. to Extraction		~95%		~93%	

* This is an estimate.

♣ Emittance from 400 MeV injection beamline.

Injected about 6E12 with >90% efficiency to extraction with operational settings